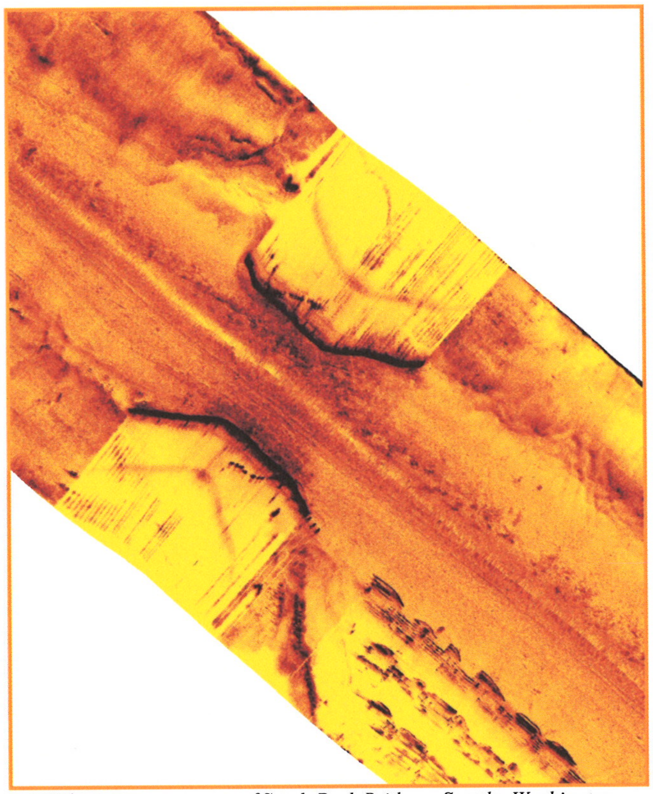
South Park Bridge Hydrographic Survey (300197)
Seattle, Washington

Summary Report – Contract No. E23011E **July 14, 2006**



Sidescan sonar image of South Park Bridge – Seattle, Washington

Prepared For:

King County
Department of Transportation
Road Services Division

Prepared By:

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Acronyms and Abbreviations

CAD	Computer Aided Design
DEA	David Evans and Associates, Inc.
DGPS	Differential Global Positioning System
GPS	Global Positioning System
Hz	Hertz
INS	Integrated Navigation System
JSF	Edgetech Proprietary Data Format
kHz	Kilo Hertz
LDWG	Lower Duwamish Working Group
MHHW	Mean Higher High Water
MLLW	Mean Lower Low Water
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
QC	Quality Control
RTK	Real-Time Kinematic
TIFF	Tagged Image File Format
TVG	Time Varied Gain
USACE	Army Corps of Engineers
XTF	Extended Triton Format

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Introduction

David Evans and Associates, Inc. (DEA) was contracted by Metro King County to perform a variety of tasks in support of the proposed replacement of the South Park Bridge in Seattle, Washington. These tasks included reprocessing multibeam bathymetric data collected at the site by DEA in 2003 for a separate project, researching horizontal and vertical control issues, and conducting field work to obtain sidescan sonar images to assess bottom conditions and verify the bathymetric data. A summary of the reprocessing effort, field operations, and the survey results are contained in this report.

Existing Multibeam Data (Processing and Verification)

David Evans and Associates, Inc. was approached by engineers at Metro King County in the spring of 2006 regarding the possible collection of hydrographic data at the site of the new South Park Bridge near 16th Avenue South in Seattle, Washington. During discussions on the needs of the project, DEA pointed out that a detailed multibeam bathymetric survey had been conducted in August of 2003 for the Lower Duwamish Working Group (LDWG), of which King County was a participant. It was agreed that evaluating the data for significant changes and reprocessing the data at a higher resolution would be the most reasonable and economical approach to obtaining the contours and profiles that the county engineers were seeking.

The raw data files from the 2003 survey were unarchived, reviewed for coverage and, if possible, additional sounding data was incorporated in the area of interest. The processed soundings were extracted at 1.5-foot grid spacing and imported into Trimble Terramodel software for verification with field QC single beam lines, and final contour and profile generation. During the field operations, several transects were made with a single beam echosounder to obtain profiles of the bottom, both across the river and along the channel, to compare with the multibeam data to establish that no significant bottom changes had occurred since the multibeam data was collected in August of 2003. The profiles were compared to the 2003 multibeam data using Trimble Terramodel software. The 2006 single beam data agreed very closely with the multibeam data, with average variations within +/- 0.1 foot. No significant changes in the bottom morphology were noted along the comparison transects.

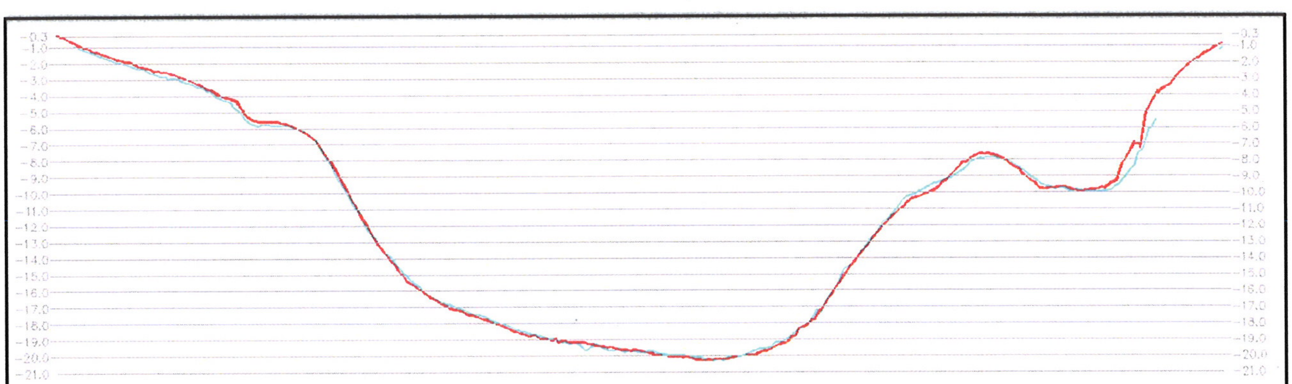


Figure 1. Typical comparison of bathymetric profiles. 2003 Multibeam (red) and 2006 Singlebeam (cyan). VE = 5X

The 1.5 foot gridded data were exported in digital format as two X,Y,Z files (one on the original 1960-1978 epoch MLLW (mean lower low water) vertical datum, and one using a 2.41-foot adjustment for export on the NAVD88 vertical datum). Copies of these files are contained on the CD in Appendix A. Details of the data collection and processing can be found in the report produced for the LDWG. Additional information regarding the collection and processing of the 2003 multibeam data can be found on the internet at: www.ldwg.org/Assets/Bathymetry/Bathymetry_report.pdf.

Sidescan Sonar

Theory of Operation

Sidescan sonars produce images of the seafloor based on the reflection of acoustic pulses that are transmitted in a fan shape beam out to the sides of the towfish. As the sound waves travel out to the port and starboard sides, they are reflected off objects they encounter along the way, first the seafloor and then off objects on the seafloor at increasing distances. The returned acoustic signal is received by the port and starboard transducers and converted to an electrical voltage by the piezoelectric crystals, or elements, inside the transducer arrays. These voltage levels are recorded on an image processing system on the vessel relative to their time of arrival at the towfish. Every transmission of a sound pulse or "ping" produces a very narrow voltage versus time strip of reflected energy from the seafloor. As the sonar is towed along a transect line, above the seafloor, multiple strips are gathered and displayed to produce a map view acoustic image of the bottom, somewhat analogous to an aerial photograph. In aerial photographs the direction of the sun can produce shadows; in sidescan images, the acoustic pulse, where blocked by objects or the topography of the seafloor, produces "acoustic shadows."

The distance that can be mapped out from the sonar towfish is a function of the time between successive acoustic transmissions or "ping rate." Typical ping rates are on the order of tenths of seconds but can exceed four seconds on wide swath sonar systems. The actual distance the acoustic pulse can travel during one cycle is a function of the speed of sound in water. For typical seawater, 1500 meters per second is a generally accepted value. In one second an acoustic pulse can travel 1500 meters, however, due to the fact that the signal needs to go out and be reflected back, the maximum distance is cut in half to 750 meters. Therefore, a 0.1-second ping rate would yield one tenth of this 750m theoretical range, or 75 meters to port and starboard for a 150 meter total swath width.

Sidescan sonars are valuable tools because of their ability to image, virtually 100% of the seafloor within the swath. The production of long shadows which stand out well in the sonar image make this the preference for search operations. Sidescans can also show detailed outlines of bottom conditions such as sandwaves, boulder fields, pilings or debris, and changes in bottom types from fine silt to sand to gravel.

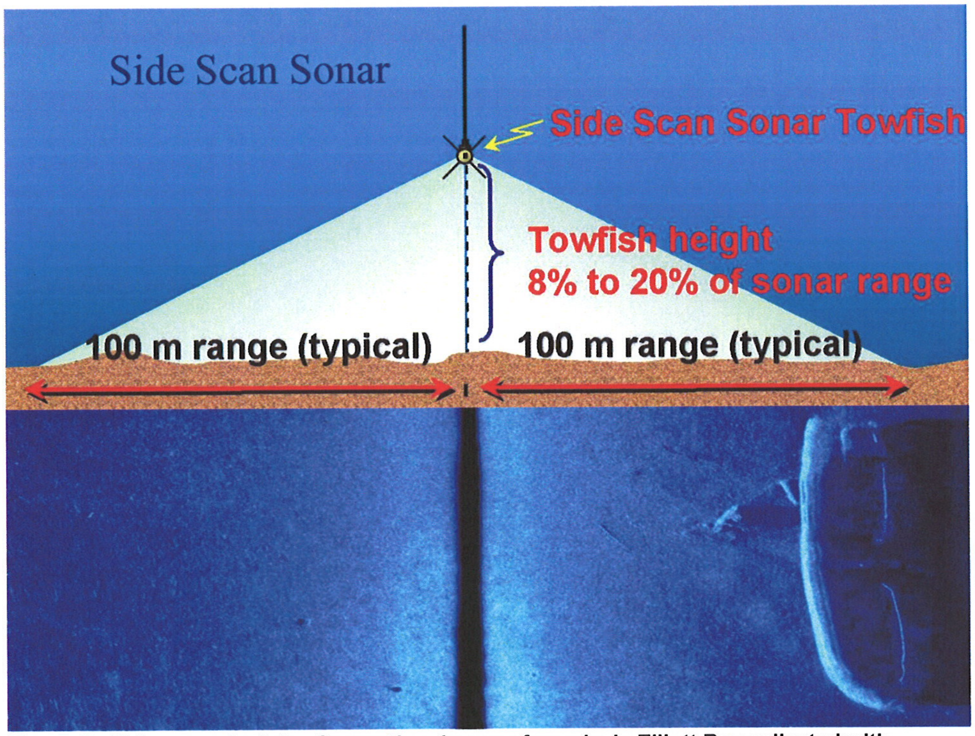
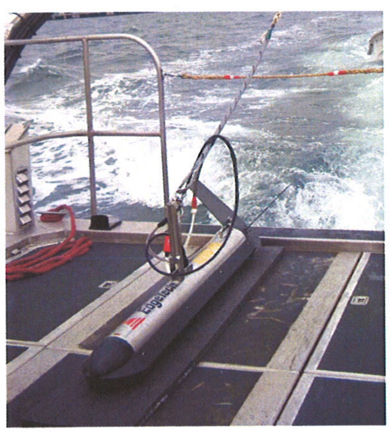


Figure 2. Sidescan principle of operation. Image of wrecks in Elliott Bay collected with DEA's Edgetech 4200 FS dual frequency sidescan.

Mobilization

The sidescan survey was conducted by DEA's senior geophysicist, a hydrographer, and a vessel operator. The survey crew mobilized the geophysical equipment on DEA's 32-foot survey vessel, the *John B. Preston,* at the Alki boat ramp in Seattle on April 12, 2006. The equipment mobilized on the survey vessel included:



- Edgetech 4200-FS Chirp sidescan sonar
- TritonElics ISIS image processing system
- Trimble MS750 RTK GPS positioning system
- Hypack integrated navigation system

David Evans' Edgetech 4200 dual frequency sidescan sonar towfish onboard the company's survey vessel John B. Preston.

Equipment Deployment and Settings

The positioning of the survey vessel was performed using an Real-Time Kinematic (RTK) Global Positioning System (GPS) system with a reference station erected on control point DEA2005. The proper settings were confirmed by conducting a position check on DEA2002 which is near the marine adjacent to the South Park Bridge. The horizontal positions checked into the surveyed values by better than 0.5 foot and the vertical elevation (for tide adjustments) agreed to the established MLLW elevation by better than 0.1 foot. In addition, a comparison between the RTK tide value and the local staff gage agreed very closely (8.57 feet vs. 8.58 feet, respectively).

The sidescan sonar was deployed off the stern A-frame of the survey vessel. The tow wire was spooled onto a hydraulic winch which allowed the towfish depth to be carefully controlled throughout the survey. Primary data acquisition was run on a 50-meter (164-foot) range (100-meter / 328-foot swath) on a 100-foot line spacing which resulted in over 200% bottom coverage. The extensive coverage was collected to ensure imaging surficial objects on multiple passes and to allow the nadir stripe (center line) of adjacent lines to be covered by overlap, in most instances, for production of a clean mosaic.

Towfish positioning was accomplished using RTK Differential GPS (DGPS) combined with cable length measurements. An onboard INS (Integrated Navigation System) recorded all navigation data and also produced a helm display showing the planned lines and distance right of left of line for accurate steerage of the vessel. The INS was also used to display background information such as the multibeam bathymetric hillshade map which helped the survey crew plan operations and anticipate bottom changes. The primary data recording system was the ISIS image processing system which recorded navigation data supplied by the Hypack INS, as well as the 410 kHz (high frequency data) and 120 kHz (low frequency data) sonar signals. The data format was 16-bit .XTF (extended triton format), which is a well established industry format that can be read by a wide range of image processing systems. The high and low sonar data was also recorded in the native .JSF (Edgetech Proprietary Data Format) using Edgetech Discover software.

The survey crew monitored all systems during acquisition to assess data quality and initial feature of interest. The sidescan data quality was generally estimated at very good to excellent.

An ODOM "Echotrac" survey echo sounder was utilized to collect single-beam bathymetric profiles for verification of the older multibeam data. Prior to running the single-beam transects, a sound velocity cast was taken to establish the speed of sound through the water. An average value of 4,753 feet per second was recorded and entered into the echosounder. A standard "bar-check" was used to validate the echosounder draft and velocity settings.

Sidescan Data Processing

The sidescan sonar data was processed using SonarMAP software by Chesapeake Technologies. The high frequency data from individual lines where imported into the system where they are displayed as georectified swaths on the screen in project coordinates (NAD 83/91, WA- State Plane-North, US Feet). Each swath was adjusted for TVG (time varied gain) to produce an ever return across the swath, bottom tracked (for proper slant range correction), and adjusted spatially based on cable out records and know features (i.e., bridge piers). The geophysicist manipulated the stacking/overlap order in the software to try to produce a complete image of the river bottom. When the process was completed, a geocorrected image was output at a 0.25-foot resolution in a geoTIFF (tagged image file format). The final georeferenced image was imported into the CAD (computer aided design) systems for insertion into the project drawings.

Sidescan Data Interpretation

The data quality of the high frequency sidescan was very good. The primary mosaic shows the river bottom being fairly clean in the central region with several large drag marks oriented with the channel. These drag marks are probably associated with commercial marine traffic (i.e. tugs with barges) which transit the area. The sidescan shows the bridge footings and numerous smaller targets along each bank. Most of the small targets are rip rap which is exposed at low tide. There are several linear features; one on the North side near the bridge footing may be a pipe or cable, the other along the south bank has more of the appearance of a log or loose piling. There appear to be no partial pilings in the area of the planned bridge, however, the sidescan sonar cannot image features which exist below the mud line (i.e., buried).

Survey Control Confirmation

DEA surveyors contacted King County surveyors and discussed horizontal and vertical control in the area of the South Park Bridge project. It was determined that DEA and King County did not have common control points to insure agreement of the vertical datum, so DEA conducted a level run to check elevations between a King County point and a DEA control point at the site. The vertical control was obtained by constraining to the elevations of Control Bench Mark #SNV-5288 (Washington Council of County Surveyors Control Database). A differential level survey was performed to verify the elevation of the DEA Control Point #2002 and determined the elevation to agree to better than 0.1 foot. This difference is considered acceptable as it is well within the vertical accuracy of the bathymetric survey.

Elevation Comparison DEA#2002	
GPS Elevation from 2003 survey (NAVD88)	11.990
Level loop holding SNV5288 (NAVD88)	11.893
Difference (feet)	0.097

Definition of Vertical Datums

Vertical datums are reference planes to which vertical elevations can be referenced. In the case of the South Park Bridge project, the main vertical datums being utilized are NAVD88 and MLLW. Below are generalized definitions of these datums and other relevant terms from the Tide & Current Glossary (January 2000) published by the U.S. Department of Commerce.

MLLW (Mean Lower Low Water) *– a tidal datum. The average of the lower low water height of each tidal day over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.*

MHHW (Mean Higher High Water) *– a tidal datum. The average of the higher high water height of each tidal day over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.*

National Tidal Datum Epoch *– the specific 19-year period adopted by the National Ocean Service as the official time segment over which the tide observations are taken and reduced to obtain mean values for tidal datums. It is necessary for the standardization because of periodic and apparent secular trends in sea level.*

When the 2003 multibeam bathymetric survey was conducted, the survey team researched available information from which MLLW could be established along the Duwamish River. At that time only three points with information showing the relationship between MLLW and NAVD88 could be obtained. These datum conversions were provided by the Army Corps of Engineers (USACE) web site and, to the best of DEA's knowledge, were the only data available. The stations utilized were: 93 – Seattle; 92A – Lockheed Shipyard; and 92 – Duwamish Waterway (USACE 2003). The relationship between NAVD88 and MLLW was interpolated between Station 92A at the Lockheed Shipyard and Station 92 near 8th Street at RM 2.7. The relationship at Station 92 was held for the remainder of the project from RM 2.7 to RM 4.8, as there was no data available to develop the relationship above RM 2.7 and little change was anticipated over this reach.

The data reprocessed for the South Park Bridge project was in the higher section of the 2003 survey area and the value established from the USACE web site for station 92 "Duwamish Waterway" of -2.42 feet was used in processing the data. To go from MLLW (1960-1978 epoch) to NAVD88 2.42 feet would need to be subtracted from the MLLW elevations (i.e., -10 feet MLLW (1960-1978 epoch) = -12.42 feet NAVD88). The information from the USACE station 92 listed MHHW as 11.10 feet MLLW and 8.68 feet NAVD88. It is our best estimate that these values apply to the South Park Bridge site as well. It should be noted that the National Ocean Service, which operates the primary tide station in Seattle, has updated that station to the new national tidal datum epoch of 1983 to 2001. The effective change due to the updated epoch reduced the difference between MLLW and NAVD88 by approximately 0.15 feet, however, until tidal observations are made in the vicinity of the South Park Bridge, the exact value of MLLW (1983-2001) is not known for that location.

NOS Tide Station 9447130 – Seattle, WA		
Datum	**Epoch 1960 – 1978 (ft)**	**Epoch 1983 – 2001 (ft)**
Highest Observed Water Level (01/27/1983)	14.649	14.485
Mean Higher High Water (MHHW)	11.348	11.358
North American Vertical Datum – 1988 (NAVD)	2.510	2.346
Mean Lower Low Water (MLLW)	0.000	0.000
Lowest Observed Water Level (01/04/1916)	-4.869	-5.036

Summary

The geophysical surveys conducted for planning a replacement to the South Park Bridge were successful in depicting bottom conditions in the areas of interest. The sidescan sonar shows faily clean channel and no signs of pilings from a previous bridge. Existing, high quality multibeam data was reprocessed at a higher detail to yield contours and profiles adequate for the design objectives laid out in the scope of work. Efforts were made to research the limits of the federal navigation channel but due to a lack of response from the government agencies being queried that task was verbally eliminated from DEA's scope of work. Communications between the various survey teams established a clear understanding of the vertical control being used on the project to help ensure no problems arise due to different datasets being on different vertical datum.

APPENDIX A